

AD-A098 675

AIR FORCE WRIGHT AERONAUTICAL LABS WRIGHT-PATTERSON AFB OH F/G 14/2
VIBRATION TEST LEVEL CRITERIA FOR AIRCRAFT EQUIPMENT.(U)

DEC 80 P S HALL

AFWAL-TR-80-3119

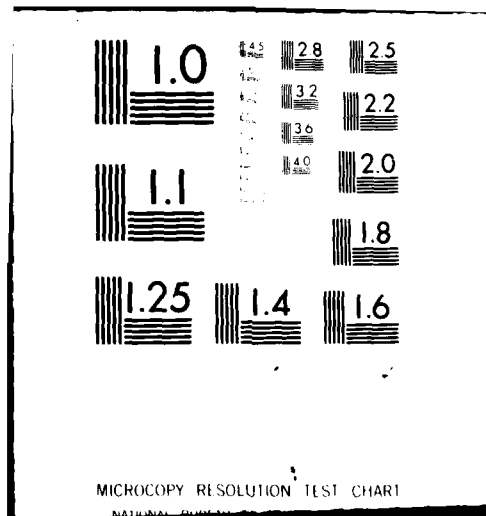
UNCLASSIFIED

NL

1 of 1
AD-A098 675



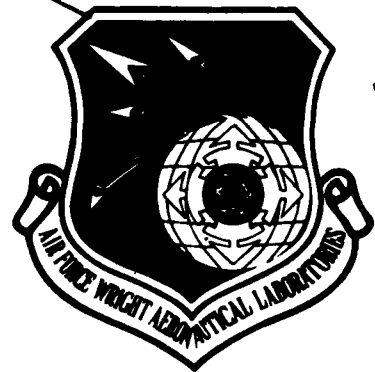
END
DATE
FILMED
5-81
DTIC



AFWAL-TR-80-3119

LEVEL

(2)



72

VIBRATION TEST LEVEL CRITERIA FOR AIRCRAFT EQUIPMENT

Preston S. Hall

Environmental Control Branch
Vehicle Equipment Division

December 1980

TECHNICAL REPORT AFWAL-TR-80-3119

Final Report for Period 6 November 1978 to 30 September 1979

DTIC
ELECTE

MAY 11 1981

A

Approved for public release; distribution unlimited.

DTIC
FILE COPY

FLIGHT DYNAMICS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

81 5 08 070

NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or other wise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

This technical report has been reviewed and is approved for publication.



PRESTON S. HALL
Combined Environments Test Group
Environmental Control Branch

FOR THE COMMANDER



AMBROSE B. NUTT
Director
Vehicle Equipment Division

"If your address has changed, if you wish to be removed from our mailing list, or if the addressee is no longer employed by your organization, please notify AFWAL/FIEE, WPAFB, Ohio 45433 to help us maintain a current mailing list."

Copies of this report should not be returned unless return is required by security considerations, contractual obligations, or notice on a specific document.

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM	
1. REPORT NUMBER AFWAL-TR-80-3119 ✓	2. GOVT ACCESSION NO. AD-A098	3. RECIPIENT'S CATALOG NUMBER 675	
4. TITLE (and Subtitle) Vibration Test Level Criteria for Aircraft Equipment	5. TYPE OF REPORT & PERIOD COVERED Final Report for period of 6 Nov 1978 - 30 Sep 1979		
7. AUTHOR(s) Preston S. Hall	6. PERFORMING ORG. REPORT NUMBER		
9. PERFORMING ORGANIZATION NAME AND ADDRESS Flight Dynamics Laboratory (AFWAL/FIEE) Air Force Wright Aeronautical Laboratories Wright-Patterson AFB, Ohio 45433	8. CONTRACT OR GRANT NUMBER(s)		
11. CONTROLLING OFFICE NAME AND ADDRESS Flight Dynamics Laboratory Air Force Wright Aeronautical Laboratories Wright-Patterson AFB, Ohio 45433	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Project 2402 Task 240204 Work Unit 24020423		
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 1234	13. REPORT DATE December 1980 1704		
	15. SECURITY CLASS. (of this report) Unclassified		
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.			
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)			
18. SUPPLEMENTARY NOTES			
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Vibration CERT Prediction MIL-STD-781C Aircraft Equipment Test Levels			
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This study details inhouse efforts that recommend vibration test level criteria for reliability of aircraft equipment. The study assesses the impact of current vibration test level criteria on the resultant reliability statistics of aircraft equipment. Problems of profiling mission vibration environmental stresses as compared to other environmental stresses are analyzed. An analysis of the readily available tools to determine the vibration stresses is also conducted. A comparison is made of various vibration exposure times and levels for a number of equipment under multiple tests. The resulting reliability			

392660

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

under the multiple tests is compared to field reliability data for the equipment studied.

62
SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

FOREWORD

This report was prepared by the Combined Environments Test Group of the Environmental Control Branch, Vehicle Equipment Division, Air Force Wright Aeronautical Laboratories (AFWAL/FIEE), Wright-Patterson Air Force Base, Ohio. This report contains the results of an inhouse research program to investigate the methods for formulating vibration test conditions used in MIL-STD-781 and Combined Environment Reliability Testing (CERT) and recommending future vibration test level criteria for aircraft equipment.

This work unit was conducted from 6 November 1978 to 30 September 1979 under work unit 24020423 with Preston S. Hall as project engineer.

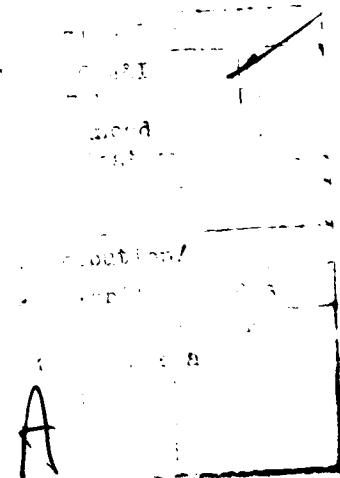


TABLE OF CONTENTS

SECTION		PAGE
I	INTRODUCTION	1
II	RELIABILITY TESTING VIBRATION CRITERIA BACKGROUND	3
III	VIBRATION SPECTRA GENERATION	10
IV	ANALYSIS	20
V	CONCLUSIONS AND RECOMMENDATIONS	23
	REFERENCES	24

LIST OF ILLUSTRATIONS

FIGURE		PAGE
1	Typical Mission Flight Profile	5
2	Random Vibration Spectrum - Avionics Bay Radio Location	6
3	Jet Aircraft-Random Vibration Test Envelope	7
4	Test Profile Generation Logic Diagram	11
5	Vibration Input to Primary Structure	16
6	Random Vibration Faults	21

LIST OF TABLES

TABLE		PAGE
1	MIL-STD-781C Jet Aircraft-Random Vibration Test Criteria	8
2	Typical Mission Profile - Air Superiority Fighter	14
3	Typical Mission Profile - Interdiction Fighter	14
4	Typical Mission Profile - Transport/Cargo Aircraft	15
5	Equipment Test/Failure Rate Correlation, Percent of Vibration Exposure, and Level	18

SECTION I

INTRODUCTION

This report focuses on the methodologies used to formulate the vibration conditions used during each test sequence of the Combined Environment Reliability Test (CERT) and to assess the impact of the resultant reliability statistics. Section II points out the problems of mission profiling vibration environmental stresses as compared to other environmental stresses. This is followed by a description of the general approach to vibration test condition formulation utilized for each of the three test sequences of the CERT program.

The purpose of the CERT Evaluation Program, conducted by the Air Force Wright Aeronautical Laboratories (AFWAL), is to evaluate the effectiveness of CERT for early identification of deficiencies and to provide insight into how the equipment will perform in operational service (Reference 1). In this program, up to ten different equipment items will be exposed to up to three different levels of environmental simulation; namely, Full CERT, CERT Without Altitude, and MIL-STD-781C Appendix B (Reference 2). This program is to determine the degree of correlation between these three different test sequences and the actual field reliability in terms of failure rates and modes. Environment mission profiles simulated by Full CERT include altitude, cooling air temperature, cooling airflow, cooling air humidity, random vibration, input voltages, and on/off cycling. All environments of the mission profiles are developed from either actual field data or by use of computerized models based on expected aircraft parameters. The environmental profiles for the MIL-STD-781C tests are in accordance with the standardized profiles of Appendix B of said standard.

Each of these test sequences utilized different methodologies for the establishment of test conditions. MIL-STD-781C Appendix B was the most completely defined in terms of methodology of determining test conditions, while Full CERT and CERT Without Altitude made use of many

AFWAL-TR-80-3119

readily available tools such as analytical models, measured flight test data, or engineering judgments.

SECTION II

RELIABILITY TESTING VIBRATION CRITERIA BACKGROUND

After considerable concern was expressed regarding the reliability of avionics equipment which was used in high performance aircraft, an investigation was conducted (Reference 3) to determine how many avionics field failures were environmentally induced and to define the significant environmental parameters affecting avionics reliability. The evidence was conclusive that environmental conditions are responsible for 52% of the avionics field failures, with 90% of environment related failures attributed to temperature, altitude, humidity, and vibration (Reference 3).

Current reliability test procedures do not expose avionics equipment to realistic environmental stresses, thus contributing to the poor correlation between field and laboratory failure rates and modes. AFWAL has conducted a number of reliability tests using the flight profile concept, designed around basic aircraft missions, as a straightforward approach to identify failure modes and rates on avionics equipment in the laboratory comparable with field experience. During the ongoing CERT Evaluation Program, each engineer responsible for a test in the program individually developed the flight profiles. In many cases, flight profiles were developed using measured data, analytical data, or a composite of both. Regardless of the data source used, each engineer attempted to develop profiles that were representative of the flight conditions that a piece of avionics would see in service.

As mentioned previously, the flight profiles representative of aircraft missions (combat, low altitude bombing, training, reconnaissance, etc.) form the foundation for the environments to which the avionics will be exposed. The result is a very tailorable test with parameters traceable to characteristic circumstances. The major environmental stresses that are used in the CERT Evaluation Program are temperature, humidity, altitude, and vibration. Each environmental stress, with the

exception of vibration, would have a time-varying profile that was directly related to the flight profile. Due to the limitations of vibration controllers, vibration profiles had to be structured from multiple vibration spectra representing various phases of the mission flight profile; for example, takeoff, cruise, combat, and landing (Figure 1). The resulting vibration spectra require two parameters, amplitude and frequency, to define a unique vibration stress (Figure 2). During the CERT Evaluation Program, each test engineer selected one of three techniques to generate the vibration spectra.

Since the CERT Evaluation Program was structured to compare the present MIL-STD-781 methods with the CERT concept, the conventional means for generating vibration spectra as outlined in MIL-STD-781C Appendix B was one technique used throughout the program. The criteria used in the specification are very straightforward with just two spectra shapes (Figure 3) and two equations expressing the levels for the spectra. The equations are related to the aerodynamic or acoustic induced vibrations and the only information required is Mach number, altitude, and equipment location (Table 1). The Mach number and altitude values obtained from the mission flight profiles would be related to a specific portion of the profile instead of every instant of time. A maximum of four vibration levels will be determined by: (1) takeoff, (2) maximum aerodynamic pressure [q_{max}] [high speed dash], (3) minimum aerodynamic pressure [q_{min}] [cruise], and (4) average aerodynamic pressure [q_{avg}] [combination of climb, dive, combat, etc., phases] (Reference 4).

The CERT concept of testing used two techniques of generating vibration spectra for the evaluation program. Since CERT places an emphasis on realism, flight data were often used to generate vibration spectra. Various sources of data are available for obtaining flight time histories of vibration, which can be matched very closely to characteristic mission flight profiles. The disadvantage of flight data is that data may not always be available for a specific equipment

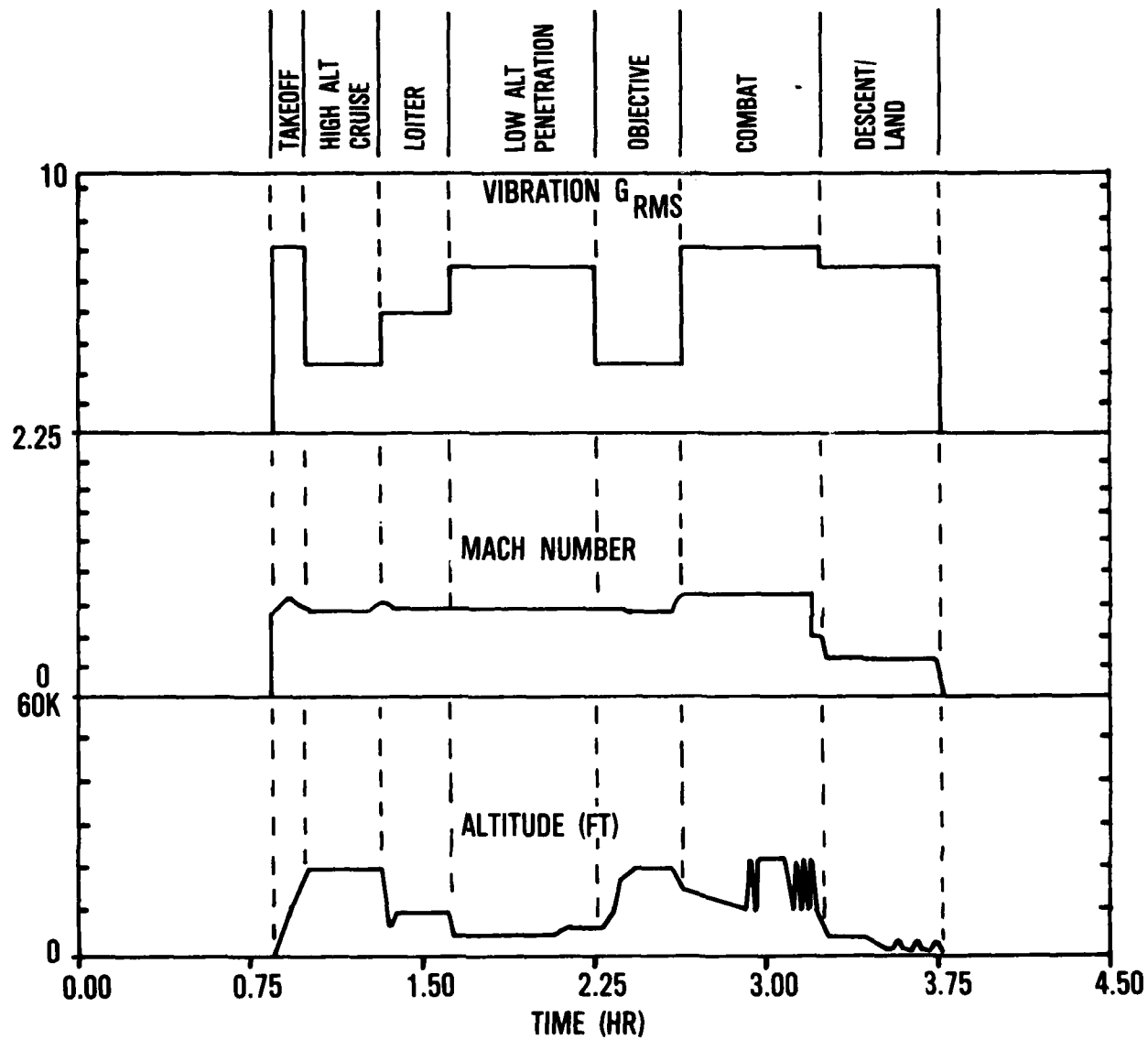


Figure 1. Typical Mission Flight Profile

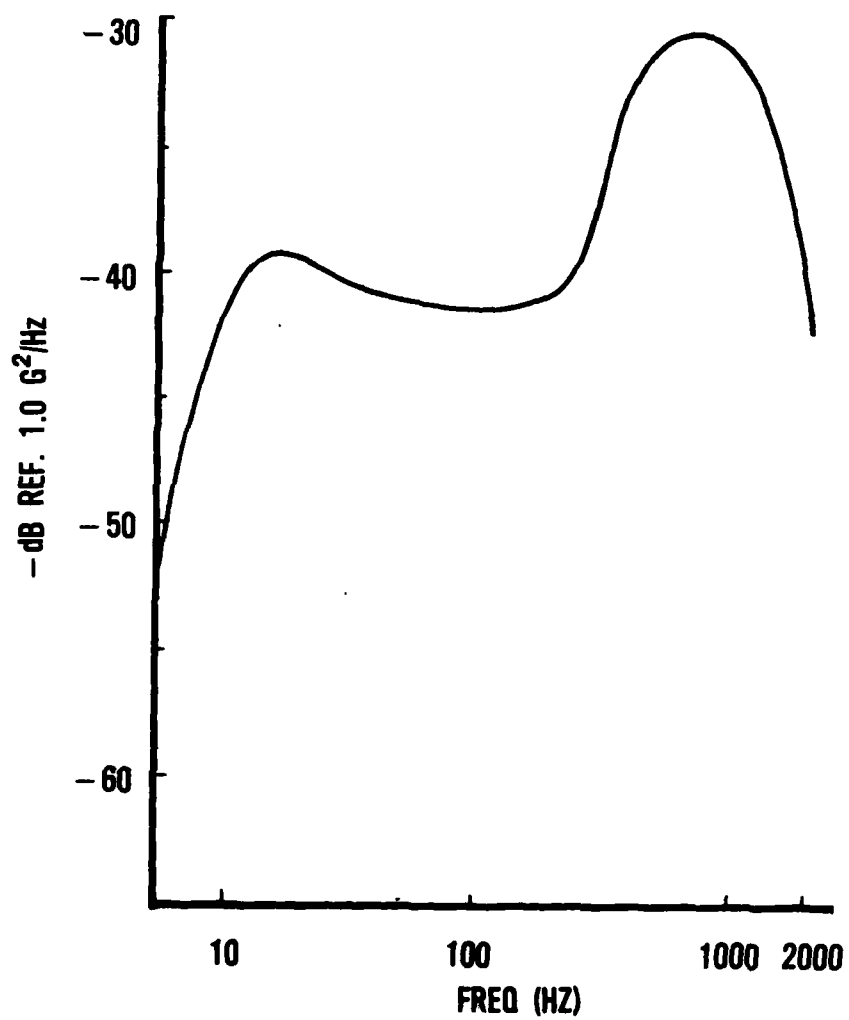


Figure 2. Random Vibration Spectrum - Avionics Bay Radio Location

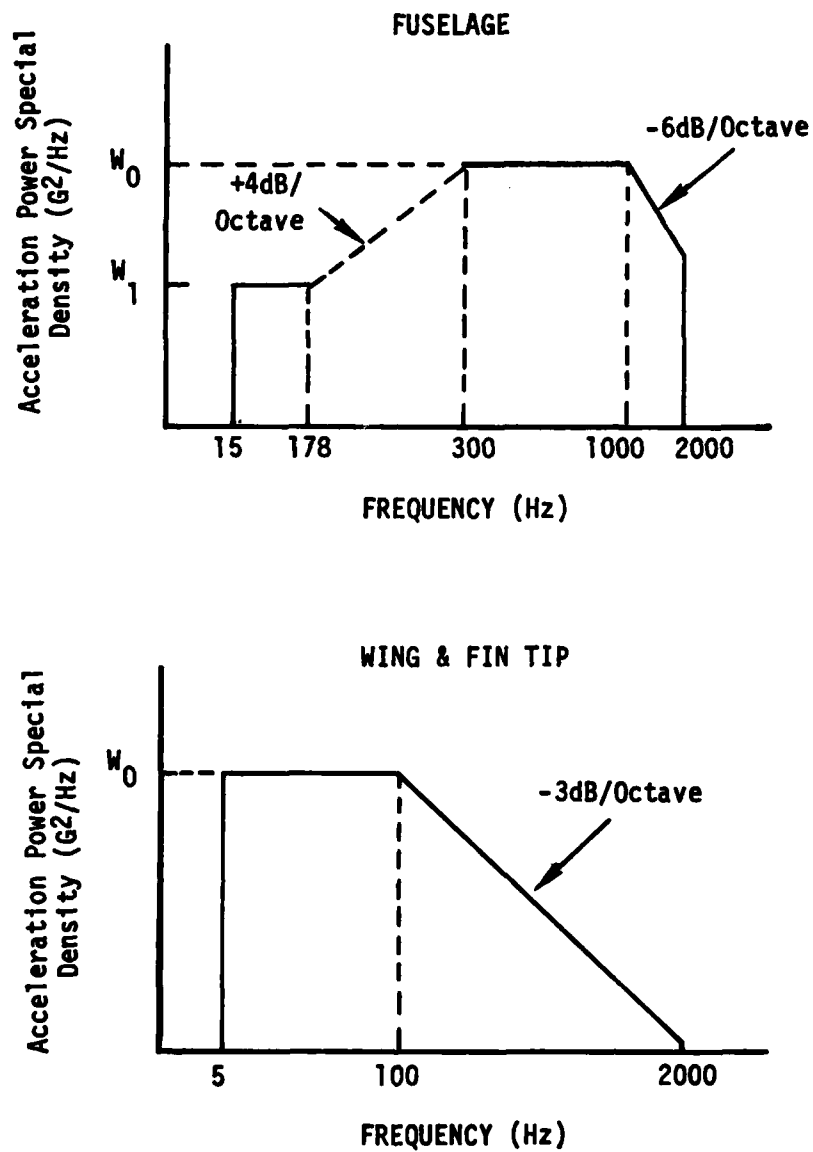


Figure 3. Jet Aircraft-Random Vibration Test Envelope

TABLE 1

MIL-STD-781C JET AIRCRAFT-RANDOM VIBRATION TEST CRITERIA

Aerodynamic Induced Vibration	
$W_0 = K(q)^2$	q = Dynamic Pressure (when $q > 1200$ psf use 1200)
$W_1 = W_0 -3$ dB	
<u>K</u>	<u>Equipment location</u>
$.67 \times 10^{-8}$	Equipment attached to structure adjacent to external surfaces that are smooth, free from discontinuities.
$.34 \times 10^{-8}$	Cockpit equipment and equipment in compartments and on shelves adjacent to external surfaces that are smooth, free from discontinuities.
3.5×10^{-8}	Equipment attached to structure adjacent to or immediately aft of surfaces having discontinuities (that is, cavities, chins, blade antennas, and so forth).
1.75×10^{-8}	Equipment in compartments adjacent to or immediately aft of surfaces having discontinuities (that is, cavities, chins, speed brakes, and so forth).
<u>SPECIAL CASE CONDITIONS</u>	
<u>Fighter Bomber</u>	
<u>Condition equipment location</u>	<u>W_0</u>
Take off/attached to or in compartments adjacent to structure directly exposed to engine exhaust Aft of engine exhaust plane (1 minute)	.7
Cruise/(same as above)	.175
Take off/in engine compartment or adjacent to engine Forward of engine exhaust plane (1 minute)	.1
Cruise/(same as above)	.025
Take off, landing, maneuvers/wing and fin tips deceleration (speed brake) (1 minute)	.1
High q (> 1000 psf)/wing & fin tips	.02
Cruise/wing & fin tips	.01
Take off/all other locations (1 minute)	.002

location. Also, this technique may not be useful to generate vibration spectra for equipment to be used in new aircraft for which no flight data exist.

Another technique of generating vibration spectra used in the CERT program is analytical prediction. The vibration prediction technique most commonly used was a computerized generation of vibration spectra that was developed by AFWAL/FIEE (Reference 5). The vibration spectra resulting from this technique are a very close approximation of flight data and relate to specific aircraft, maneuvers, and equipment locations. The prediction technique requires the availability of a computer, the prediction software, and aircraft parameters: distance of the avionic specimen from the aircraft nose, distance of specimen from skin, equipment weight, fuselage diameter, skin thickness, skin material, and mounting configuration for the location of the avionic specimen, along with specific Mach number-altitude combinations and straight-and-level or buffet turn maneuvers. At present, computer software has the capability to predict levels for only five fighter aircraft. In order for this technique to be used on aircraft other than the five preprogrammed, it is necessary to supplement the program with additional information regarding fuselage bending modes and transfer functions describing the primary and secondary structures of the aircraft in question.

The commonality of all these methods of vibration spectra generation is that all are dependent upon Mach number and altitude combinations. The spectra vary in shape and amplitude depending upon which technique is used. The methods used in the CERT concept generally resulted in more stylized spectra shapes, which seemed to satisfy the desire to achieve a degree of realism. The ability to time vary the spectra in direct relation to the time varying Mach number and altitude values of a mission flight profile is at present technically impossible due to the limitation of the state-of-the-art for vibration controllers. With all these considerations kept in mind, the issue of concern is: What is required of test criteria to identify realistic failure rates and failure modes in the laboratory?

SECTION III

VIBRATION SPECTRA GENERATION

Before an engineer can determine the vibration spectra to be used for either MIL-STD-781 tests or CERT, he must first examine the various mission/environmental profiles that are possible for the aircraft/avionic combination. Figure 4 shows a typical logic flow diagram a test engineer may use in establishing the test profiles for a piece of avionics in a specific aircraft. An individual aircraft type is designed to operate within a specific flight envelope and to fly specifically determined mission profiles. These design flight envelopes and mission profiles should be utilized when formulating the environmental profiles for a test. A number of mission profiles may be possible for one aircraft type, but statistically only two may be representative of the aircraft's major life. After the aircraft mission profiles have been determined for testing, the environmental profiles shall be generated and shall vary according to the aircraft mission profile. As pointed out earlier, the thermal, humidity, and altitude test environment profiles can have a one-to-one time varying relationship with the aircraft mission profile just as in flight. However, aircraft mission profiles must be analyzed by individual flight phases such as takeoff, climb, mission objective, descent, and landing to generate a number of vibration spectra which would make up the environmental vibration profile to which the test specimen is exposed sequentially. After the test engineer has determined what flight phases significantly impact the test, he must determine the maximum, minimum, or average conditions and Mach number-altitude combinations necessary to generate the vibration spectra. The test engineer then makes another judgment as to whether he wants multiple vibration spectra or a composite of several for the aircraft mission profile.

After determining the vibration spectra required to give a representation of vibration stresses, the engineer must give consideration to test equipment limitations. There exists a number of ways to control vibration inputs, all of which have their limitations. The devices to control

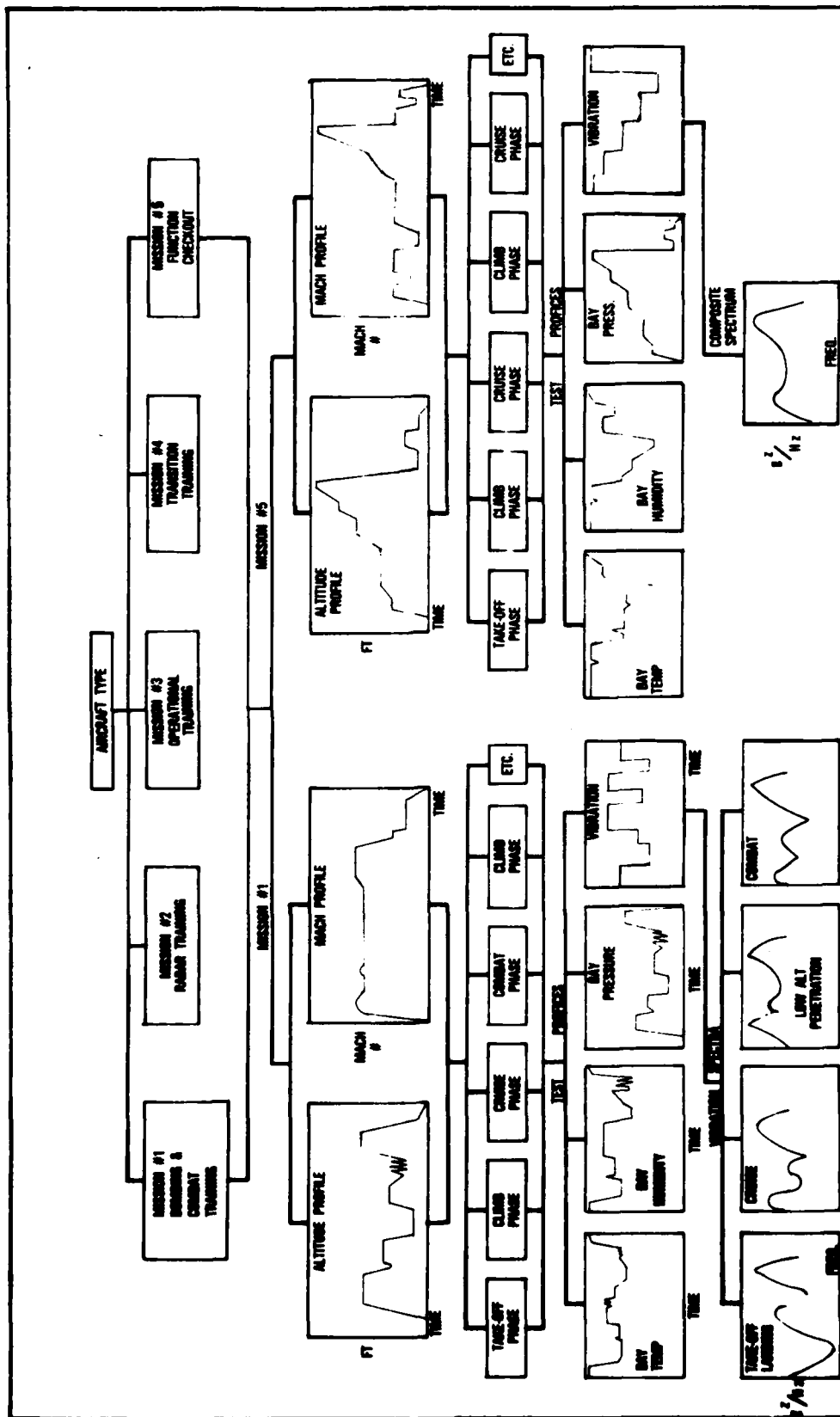


Figure 4. Test Profile Generation Logic Diagram

vibration range from simple audio recording equipment to extensive digital computer controllers (Reference 6).

The minimum level of a vibration spectrum is of concern for any vibration system. With both analog and digital controllers there exists a noise floor or a level of vibration that is so low that the controller's signal to noise capability is exceeded. The manufacturer establishes a cut-off level for a controller relative to its characteristic noise floor in order to assure good controllability. For some cases in the CERT Evaluation Program, the levels of vibration derived from flight data and analytical methods have been below the cut-off level of the controllers. A judgment must be made to either eliminate vibration exposure during these periods of the vibration profiles or choose some minimum spectrum level that the controller could handle for the total mission.

Economics is another concern if vibration requirements impose the use of more sophisticated vibration control equipment. The developer of a piece of avionics may find it economically impossible to purchase a sophisticated digital system in order to achieve the vibration requirements. The analog controller is fine for vibration spectrum control; however, the major difference between it and digital systems is that only one spectrum shape per mission simulation can be effectively controlled. Considerable time is required to establish a spectrum and there is no convenient method of storing multiple spectra that may be introduced at various times to represent different phases of a vibration profile. Early tests during the CERT Evaluation Program used analog systems, as digital controllers were not available. A single vibration spectrum was used throughout the test and the mean time between failures (MTBF) was in good correlation with field MTBF data (Reference 7).

Under MIL-STD-781 procedures for establishing vibration spectra, a number of the engineering decisions are eliminated and equipment limitations are nonexistent in the majority of cases. By definition, the engineer is still required to give consideration to the various

mission/environmental profiles that are possible for the aircraft/avionic combination to be tested. However, when design flight envelopes and specifically designated flight mission profiles are not available, the generalized mission profiles listed in MIL-STD-781C, Appendix B are to be used for development of environmental profiles.

With regard to vibration spectra generation, MIL-STD-781C, Appendix B has only two spectrum shapes and the level is dependent upon Mach number-altitude combinations obtained from actual profile data or given values in Appendix B (Tables 2, 3, and 4) (Reference 4). A constant value also must be determined from a choice of four values relating to equipment location. If the level for particular phase of the vibration profile is less than $0.001 \text{ g}^2/\text{Hz}$, vibration exposure is not required.

The criteria in MIL-STD-781 give the test engineer the advantage of determining numbers of missions, flight phases, and vibration spectra for new avionics on new aircraft for which there are no mission/environmental data. The criteria also allow the use of analog equipment to control the vibration spectra since only one shape exists and levels are easily changed. Problems with control of extremely low levels are eliminated, since the minimum cut-off level in the test criteria is well above the capability of most controllers.

With the introduction of a cut-off level for vibration under MIL-STD-781C criteria, the possibility exists that the test specimen may not be exposed to vibration during considerable portions of the tests. With the CERT concept of testing, vibration is continuous during the flight portion of a mission as long as it is within controller capabilities. As previously mentioned, the number, shape, and levels of vibration spectra used in the CERT portion of the evaluation program varied for a number of reasons, but the exposure time is continuous, or nearly so.

The project engineer for the AN/APX-76 test in the evaluation program examined the differences between MIL-STD-781C and CERT vibration in both time and levels (Reference 8). Figure 5 shows the difference

TABLE 2
TYPICAL MISSION PROFILE - AIR SUPERIORITY FIGHTER

Flight Mode	Test Phase*	% Time	Altitude (1000 ft)	Mach Number	q (psf)
Ground Runup (no AB)	A,F	4	0 to 0.5	0	-
(with AB)		1			
Takeoff	B,G	5	0.5 to 1	0 to 0.4	-
Climb (to 40,000 ft)	B,G	8	to 40	0.6	245
Cruise (500 ft)	C,H	6	.5	0.8	900
(20,000 ft)		5	20	0.9	550
(40,000 ft)		40	40	0.9	225
Acceleration	C,H	4	40 to 50	1.7	620
Combat (500 ft)	C,H	1	.5	0.85	900
(5000 ft)		1	5	0.9	1000
(10,000-40,000 ft)		2	10 to 40	2.0	1800
(50,000 ft)		3	50	2.5	1180
Descent	D,I	8	40 to 3	0.8	445
Loiter	D,I	8	3	0.4	200
Landing	D,I	5	3 to 0.5		

*See Figure B-3 of MIL-STD-781C, Appendix B

TABLE 3
TYPICAL MISSION PROFILE - INTERDICTION FIGHTER

Flight Mode	Test Phase*	% Time	Altitude (1000 ft)	Mach Number	q (psf)
Ground Runup (no AB)	A,F	4	0.5	0	-
(with AB)		1	0.5	0	-
Takeoff	B,G	4	0.5 to 1	to 0.4	-
Climb (to 35,000 ft)	B,G	5	to 35	.6	245
Cruise (500 ft)	C,H	27	.5	0.8	900
		32	35	0.9	280
Acceleration	C,H	3	35 to 50	1.7	620
Combat (500 ft)	C,H	2	.5	0.85	900
(10,000-35,000 ft)		1	10 to 35	2.0	1800
(50,000 ft)		4	50	2.5	1180
Descent	D,I	6	40 to 3	0.8	445
Loiter	D,I	7	3	0.4	200
Landing	D,I	4	3 to 0.5		

*See Figure B-3 of MIL-STD-781C, Appendix B

TABLE 4
TYPICAL MISSION PROFILE-TRANSPORT/CARGO AIRCRAFT

Flight Mode	Test* Phase	% Time	Airspeed Knots**	q (psf)
Ground Runup	A,F	5	-	-
Takeoff/Climb	B,G	5	to 260	200
Cruise High Altitude 36K	C,H	70	240	210
Medium Altitude 22K		5	250	225
Low Altitude 1K		10	350	400
Descent/Land	D,I	5	140	100

*See Figure B-1 of MIL-STD-781C, Appendix B

**Knots Equivalent Airspeed

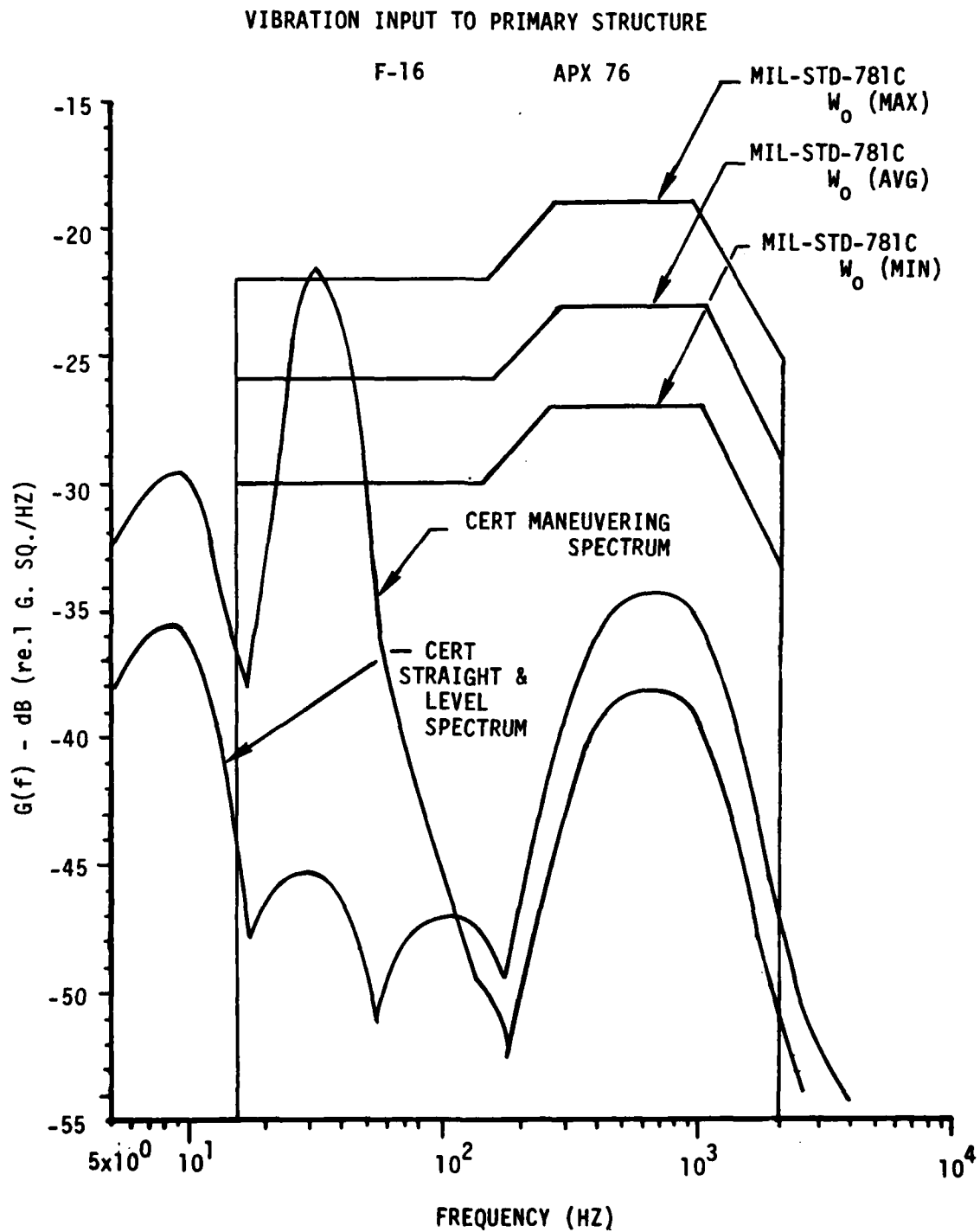


Figure 5. Vibration Input to Primary Structure

in the two test concepts' spectra. During CERT, the straight-and-level vibration spectrum was applied 63 percent of the time to the equipment under test and the maneuvering spectrum was applied 18% of the time, for a total of 81%. In a MIL-STD-781C, Appendix B test, no vibration would be applied 70% of the time, $W_{o(max)}$ 2% of the time, $W_{o(min)}$ 8% of the time, and $W_{o(avg)}$ 20% of the time, for a total of 30% of a mission having vibration. The MIL-STD-781C, Appendix B vibration levels are significantly greater than those used during CERT. As a matter of fact, the CERT straight-and-level spectrum is below the level specified in MIL-STD-781C, Appendix B, where random vibration need not be applied.

Table 5 lists equipment tested in the CERT Evaluation Program, and it is apparent in the majority of the cases that CERT revealed a better correlation of failure rates to field data than MIL-STD-781C. For the few cases where MIL-STD-781C failure rates were much greater than field (APX-76 and APX-101), it was determined that the failures were attributed to unrealistic environmental extremes of temperature and humidity. Table 5 points out the vast difference in vibration exposure time the avionics experienced for a total mission for both MIL-STD-781C and CERT. Of these tests, all equipment items were exposed to levels for CERT that were equal to, and in most cases less than, the minimum level for MIL-STD-781C. The levels for CERT were derived primarily by the Flight Dynamics Laboratory computer predictive technique and was checked against flight data when available. The aircraft application varied and also may be found in Table 5.

After the original three test sequences in the evaluation program had been completed on the AN/APX-101 to A-10 conditions, an additional series of test cycles was to be conducted to FULL CERT criteria with the exception of vibration. Instead of using the highly stylized computer-predicted vibration spectra, the test was to use MIL-STD-781C, Appendix B spectra, but the cut-off level exclusion was eliminated. This would provide for vibration to be continuous throughout the test.

TABLE 5
EQUIPMENT TEST/FAILURE RATE CORRELATION, PERCENT OF VIBRATION EXPOSURE, AND LEVEL

A/C	Equipment	FIELD		MIL-STD-781C			FULL CERT		
		MTBF	MTBF	% of Vib Exp Time Over Total Mission	Overall Vib Level (g's RMS)	MTBF	% of Vib Exp Time Over Total Mission	Overall Vib Level (g's RMS)	
F-15	AN/APX-76	133	57	63.0	1.33	200	100.0	0.44	
A-7	AN/ASN-90	156	338	80.0	1.17	101	100.0	1.49*	
F-15	AN/APX-101	273	42	2.0	1.33	252	100.0	0.073	
F-111	AN/ARC-109	95	348	0.3	1.66	85	100.0	0.37	
F-5	AN/ARN-84	170	188	22.0	1.93	157	100.0	0.55	

*Composite spectrum. All other levels are based on straight-and-level or cruise conditions.

AFWAL-TR-80-3119

but the levels would never go below $0.001 \text{ g}^2/\text{Hz}$. This level was found to be greater than the predicted stylized levels and measured data. The intent of using the simplistic vibration criteria, along with the other realistic environmental profiles, was an attempt to evaluate the need for stylized vibration profiles and the effect of vibration exposure time.

SECTION IV

ANALYSIS

The CERT Evaluation Program, to date, has tested six pieces of avionics. Each test has utilized at least two, and sometimes all three, methods of generating vibration spectra previously mentioned. For all avionics tested data were available from previous tests to MIL-STD-781C, field reliability (AFM 66-1), and flight data was also available. The data from the evaluation program showed that testing by MIL-STD-781C results in large deviations of test MTBF data compared to field data, while testing with CERT results in MTBF data approximate to the field data.

The obvious difference with regard to vibration between MIL-STD-781C and CERT is the exposure time. An examination of test/field MTBF data correlation showed a higher level of correlation under CERT than MIL-STD-781C for equipment/test combinations with continuous vibration. This does not imply that vibration alone is responsible for equipment failures. What this does indicate is that some synergistic effect from combined thermal and vibration cycling is responsible for the realistic determination of failure rates and modes.

From available literature examined (Reference 9), it was found that the presence of very low amplitude vibration for a long period of time does have a significant impact on equipment life (Figure 6). Even though these data are for a single environmental condition which is much less complex than combined environments, they still suggest the importance of vibration-caused failures over a long period of time, even at low amplitudes.

At this time, testing of the APX-101 to A-10 conditions is continuing with over 1000 hours of ON time. Although tests have already been conducted on this equipment to Full CERT and MIL-STD-781C, Appendix B,

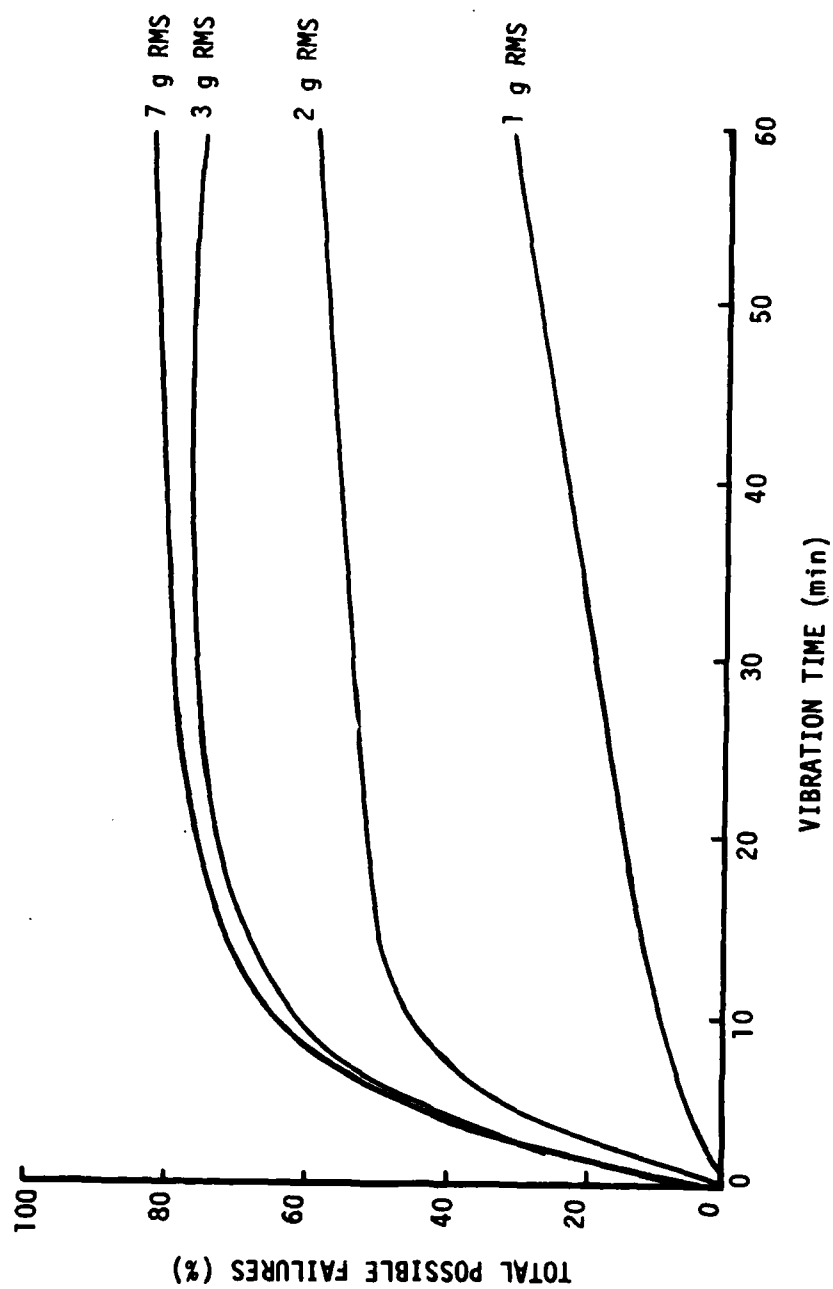


Figure 6. Random Vibration Faults

it is now being tested to Full CERT again but with MIL-STD-781C, Appendix B vibration spectra in lieu of the highly stylized spectra. In cases where the vibration level was calculated to be below the standard's cut-off level, vibration was to be continuous over that range at the cut-off level. Although the level may be higher than actual field conditions, and if the findings in the referenced literature (Reference 9) are true even in combined environment cases, the failures may propagate at a faster rate and then level off. It was indeed found in the modified CERT that the only two failures to date were discovered in the first test cycle.

Although these data are not enough to give overwhelming support to the vibration issue, they also do not refute the claim for simpler test criteria. What is implied, though, is that the payoff from using the MIL-STD-781C vibration spectrum for CERT may be less expensive testing, increased ease of implementation, and better test results over present MIL-STD-781C criteria. The test results still must have additional data to increase confidence of the preliminary results.

Considerable savings in testing would be the result if laboratories and manufacturers did not have to obtain additional peripheral test equipment and software to generate highly sophisticated tailored vibration spectra. Finally, since the random vibration spectra in MIL-STD-781C are commonly used and accepted, continued use of some form of these spectra may result in less confusion for future test concepts.

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

From the tests run to date for the CERT Evaluation Program, it is apparent that continuous vibration throughout the test mission may contribute to a strong degree the good correlation between field and laboratory MTBF of internally carried aircraft equipment. With the variance in engineering judgments made in the generation of vibration spectra (numbers, shapes, and levels), it appears that highly stylized vibration spectra may not be technically or economically necessary to achieve realistic results.

By continuing the CERT concept of testing with MIL-STD-781C vibration spectra, it is felt that CERT would be more widely accepted for economic and simplicity reasons. The stipulation in MIL-STD-781C criteria with no vibration exposure for levels calculated below $0.001 \text{ g}^2/\text{Hz}$ should be eliminated. Instead, vibration exposure should continue at $0.001 \text{ g}^2/\text{Hz}$ until a phase in the mission profile requires a higher level. The need for highly sophisticated vibration controllers, digital computers for spectra generation, and extensive software/programming would not be required to perform the vibration portion of a reliability test. With a simplistic and yet technically correct approach to generating vibration spectra for a reliability test, the resulting data are trackable and confidence increased for procurement buys of avionics equipment.

REFERENCES

1. "Combined Environment Reliability Test Evaluation Program Plan," June 1976, plus revision dated 1 November 1977.
2. R. Scott, Capt, USAF, "Joint ASD/AFWAL Combined Environment Reliability Test (CERT) Evaluation Program," Proceedings of 24th Annual Technical Meeting of the Institute of Environmental Sciences, Ft Worth, Texas, April 1978, pp 34-37.
3. A. Dantowitz, G. Hirschberger, and D. Pravidlo, "Analysis of Aeronautical Equipment Environmental Failures," AFFDL-TR-71-32, May 1971.
4. MIL-STD-781C, "Reliability Tests: Exponential Distribution," 21 October 1977.
5. R. Sevy and M. Haller, "Computer Program for Vibration Prediction of Fighter Aircraft Equipments," AFFDL-TR-77-101, November 1977.
6. R. Polallus and G. Hirschberger, "Interim Report Utilization of Taped Random Spectra for Vibration Testing," Grumman Aerospace Corp.
7. D. Prather and D. Earls, "A Flight Profile Combined Environments Reliability Test of the AN/APQ-146 Terrain Following Radar System," AFFDL-TR-76-20, March 1976.
8. E. Stanczak, "An Evaluation of the Combined Environment Reliability Testing of the RT868A/APX-76 IFF Interrogator Receiver-Transmitter," AFFDL-TR-77-132, December 1977.
9. F. Kobe and G. Hirschberger, "An Investigation to Determine Effective Equipment Environmental Acceptance Test Methods," ADR 14-04-73.2, April 1973.
10. D. Prather and A. Burkhard, "Combined Environment Reliability Test of the CN-1260/ASN-90(V) Inertial Measurement Unit," AFFDL-TR-79-3043, April 1979.
11. D. Earls, "An Experimental Combined Environment Reliability Test of the AN/ARC-164 Radio Set," AFFDL-TR-78-127, October 1978.
12. D. Hart, "A Test Plan for Combined Environment Reliability Test Plan for the APX-101 Radio Receiver-Transmitter," 25 July 1978.

EN

DAT

FILM

5

-8

DTI